

LIBRARY



SOCIETY OF AUTOMOTIVE ENGINEERS, INC.
Two Pennsylvania Plaza, New York, N. Y. 10001

Heavy Duty Over-Snow and Off-Highway Vehicles

Ross V. Eskelson
Esson Industries

SOCIETY OF AUTOMOTIVE ENGINEERS

**National Farm, Construction and Industrial
Machinery Meeting
Milwaukee, Wis.
September 8-11, 1969**

690573

690573

Heavy Duty Over-Snow and Off-Highway Vehicles

Ross V. Eskelson
Esson Industries

DURING THE PAST FEW years, there has appeared on the market an ever-increasing number of vehicles which go under the title of ATV, or All Terrain Vehicles. The ATV nomenclature is one which came into use during several development programs which were sponsored by the military. The producers of these off-highway vehicles designate them as all terrain vehicles, but it is really a misnomer, as none of them come very close to meeting the requirements of, and really living up to, the title of all terrain vehicles. While most of the new vehicles give greatly increased mobility over the standard 4-wheel drive vehicles which have been in wide use for years, such as the jeep, power wagon, and military multiwheel drive vehicles, all of them are still quite limited in their ability to traverse a wide variety of terrains.

Most of these all terrain vehicles are multiwheeled, Terra-tired types, or have the low ground pressure tires which also have a track that can be adapted when the going gets rough, but their performance is definitely limited if one considers the broad spectrum of environments in which these vehicles should operate. Most of the vehicles do quite well when operating in swampy or marshy ground for which most of them were designed, and particularly if the marsh contains much organic material, to provide some traction, and a floating mat which gives some support to the vehicle. However, when most of the vehicles get into the very slick mud areas, the performance rapidly falls off; and some of them fail completely when trying to negotiate the twilight or gray

zone between fairly firm ground and the semiliquid areas of tidal flats and similar types of terrain.

Many of the low pressure, all wheel vehicles are quite successful when they have tires of sufficient flotation to give a true amphibian type operation to the vehicle. The same lightweight vehicles, however, are quite unsuccessful when attempting to operate in some of the softer snow conditions. The reason for this is principally that successful over-snow transportation requires a ground pressure of something less than 1 psi, and most of the tired vehicles are operating around 2 psi or above. The radius of the wheels also gives an effect of fracturing on the snow structure when compared with the broad, flat surface presented to the snow by a track.

In this paper, I wish to consider vehicles which are generally heavier than the small all terrain vehicles which are so popular on the market today, and most of the vehicles considered in this paper will be relatively specialized. They are special because of the particular job they must perform, and also they have been designed principally to be very successful in one environment, with lesser capabilities in other environments. The manufacturers of most of the heavy-duty, over-snow and off-highway vehicles have realized the relative impossibility, at least in the present state-of-the-art, of producing a vehicle which can be made light enough to be successful in all environments and still rugged and heavy enough to stand the constant abuse given off-highway vehicles.

If I were to choose one type vehicle which would probably

ABSTRACT

Many vehicles today use the title All Terrain Vehicle although none of them have true all terrain capabilities. To provide the performance capabilities required and the dependability needed, designers still find it necessary to design for the specific use intended instead of being able to

design a universally accepted vehicle for many purposes.

The introduction of recently available hydrostatic components and suspension components which eliminate the need for lubrication should extend the versatility and dependability of off-highway vehicles.

operate in the broadest variety of environments, it would probably be some amphibious version of the more successful over-snow vehicle. A typical vehicle in this category is the 1300 Series Swamp Spryte, as produced by Thiokol Chemical Corp., as this vehicle does a relatively successful job in most snows, but in addition, will handle a wide variety of swamps and has true swimming capabilities. To maintain its ability to traverse the light snows, and also the more severe swampy and tidal flat conditions, the vehicle must necessarily be built very light, and this can only be done at some sacrifice in life and dependability. At best, these vehicles are a compromise even though relatively successful in most terrains, but when one must depend upon excellent operating characteristics in the softest snows, one must go to vehicles with more track area, larger size, and track cleat designs which give increased climbing capabilities.

I will now review what I consider to be the best vehicles for operation in a variety of environments, and then, in summary, indicate where I believe the next few years will lead the off-highway vehicle manufacturers in their attempt to develop vehicles which are dependable and will still meet the widest combination of operating environments.

VEHICLE CATEGORIES BY ENVIRONMENT

Heavy-duty and off-highway vehicles can be categorized several ways. However, I have chosen to use the categories of surface and climatic environments of different areas where they operate. The first category which generally separates these vehicles is the antarctic conditions. The antarctic area is characterized by extreme cold, by relatively crystalline, hard snow conditions, and these snow conditions are interlaced with deep crevasses which cause additional danger when operating in this area. In certain areas, in addition to the snow and ice found in the antarctic, there are sands, particularly around McMurdo Sound, which are very abrasive to the track and track support mechanism of any vehicle.

The second category is the arctic and subarctic areas. These areas are characterized by the tundra in the north, with glacial silt and intermitted honey-comb type lakes. In the subarctic, we characteristically find the muskeg, and in some areas, as in the Aleutian Islands and similar areas, we find relatively large areas of glacial silt or volcanic sand. Both of these materials being very abrasive to the vehicle.

The third category is that of the general swamp conditions, or tidal flat conditions, found in a wide area of the world. In the United States, many of the southern states have both the slick tidal-flat muds, as well as the swamps which are full of very heavy vegetation. These same conditions are found in many other areas of the world, particularly these conditions are found in parts of Viet Nam, such as the Mekong Delta, where there are great areas of tidal flats with extremely slick muds.

The fourth category is one which requires true amphibious vehicles in order to operate in them, and these areas are characterized by swamps which are cut by canals or other open waterways, or the deeper swamps which have little surface vegetation.

The fifth general category is that of deep snow. The wide variety of snow and snow conditions which must be encountered has been pointed out in an earlier paper by the author, as by others. To be successful, the vehicle must be capable of operating under any of the snow and temperature conditions found in the snow belt states. Further differentiation may be made between the vehicles to meet the requirements of the special vehicle users, and these being broken down into users such as:

1. The ski resort users who use them principally for maintenance and slope grooming.
2. The utility companies, for line maintenance.
3. The ranchers and other commercial users of over-snow vehicles.
4. Those who use a larger vehicle mainly for sports or personal transportation into the mountains where loads must be carried which are beyond the capabilities of the smaller sport type, ski-steered over-snow vehicle. Further examination of the above mentioned categories will now be made with a description of those vehicles which are successfully traversing the terrain and environments as found in the different locations or categories.

ANTARCTIC ENVIRONMENT - Extremely cold temperatures and long distances to be traversed are the two main problems when operating off-highway vehicles in the antarctic areas. There are other lesser problems in operating vehicles in the antarctic, but the most severe problems are those associated with the very cold temperatures and the great distances which must be traveled with little or no support for the vehicle in the way of fuel or maintenance facilities. Temperatures are often encountered in the antarctic which go to 90 deg below zero, and distances traveled are sometimes over 1000 miles with only limited air support being available for refueling or maintaining the vehicles. While vehicles which utilize rubber tires and rubber-belted tracks have little difficulty when operating in the arctic and subarctic, and some warmer areas of the antarctic, they have not proven too satisfactory under some of the extreme conditions in the antarctic. As a result of this, the vehicles which have done the outstanding job in the antarctic are those produced by the Tucker Sno-Cat Corp. of Medford, Ore., which uses metal tracks. Early long traverses across the antarctic were made in Tucker Sno-Cat vehicles, and these vehicles were specially built and specially equipped for insuring the dependability of the vehicles and providing the life-sustaining functions for the operators of the vehicles. Most of these vehicles were very large and equipped with specially insulated cabs and great fuel capacities, allowing them to travel great distances without refueling.

Other vehicles have been relatively successful in special areas of the antarctic, but for the long, arduous traverses, the Tuckers have done the best job. Some special vehicles, as constructed by Thiokol Chemical Corp., have done excellent work on several research projects operating out of McMurdo Sound, as have vehicles produced by the Robin Nodwell Corp. of Calgary, Alta., Canada. Both of these vehicles use rubber-tired wheels and flexible rubber belts with nylon cores. The

main advantage of the rubber tires and belts, of course, is greater life of the tracks with the minimum of maintenance or lubrication problems. Some of the earliest, successful transportation in the antarctic was done with specially modified Ferguson farm tractors which had a metal link track running around the rear tire and an idler tire. Fig. 1 shows

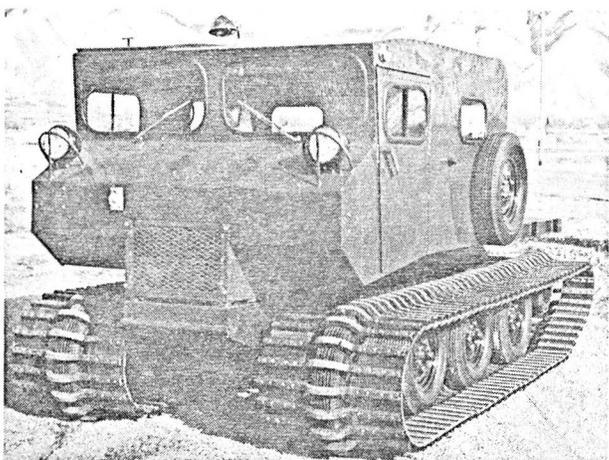
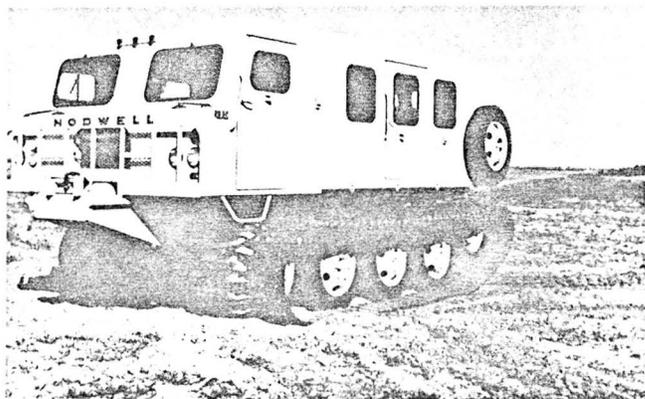


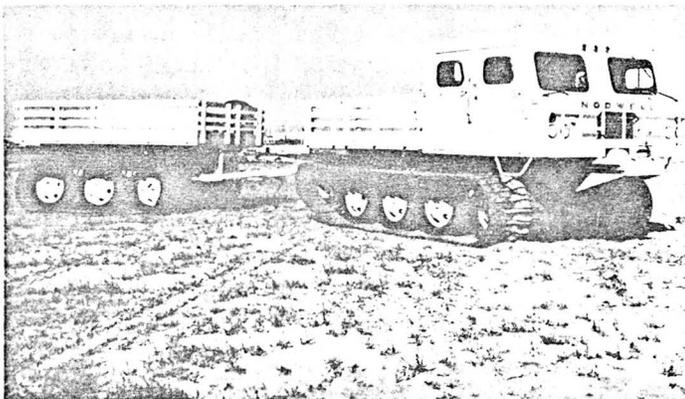
Fig. 1 - Thiokol Chemical Co. Model 602 used in the antarctic near McMurdo Sound

a specially equipped vehicle of Thiokol. Fig. 2 shows some vehicles used in the antarctic, constructed by the Robin Nodwell Co. One problem encountered operating in the antarctic is having to cross the crevasses which are in the ice cap. They are often covered up or bridged over by the wind-driven snows and can be from a few inches to several feet wide, and sometimes open to great depths. Because of the danger to the vehicle and its operators, most traverses are made with some kind of a specially equipped lead vehicle which electronically searches for the crevasses or has some kind of a probe out ahead of the vehicle to try to locate the crevasses areas before the vehicle drives into them. Successful operation in the antarctic is not only characterized by the dependable operating characteristics of the vehicles, but by the extensive planning for maintenance and support of the vehicle which must be accomplished in great detail before long traverses are attempted in the antarctic,

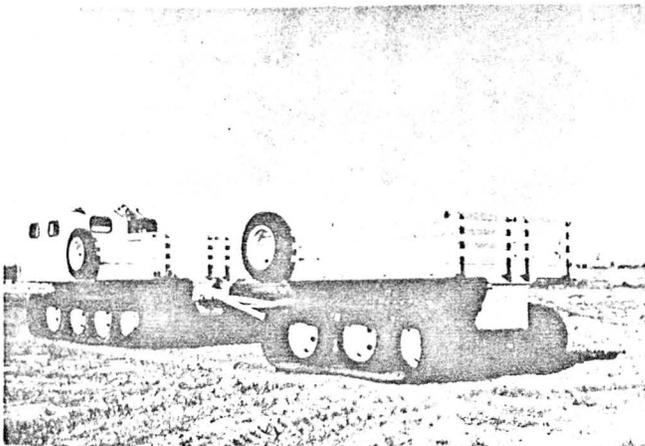
ARCTIC AND SUBARCTIC AREAS - In the arctic area north of the Brooks Range in Alaska, where great oil exploration activity is presently going on, the surface conditions are principally those of tundra, which is supported by permafrost. During the summer months, the glacial silt and open arctic rivers are encountered, and also the honey-combed type lakes formed from the melting of the ice during the



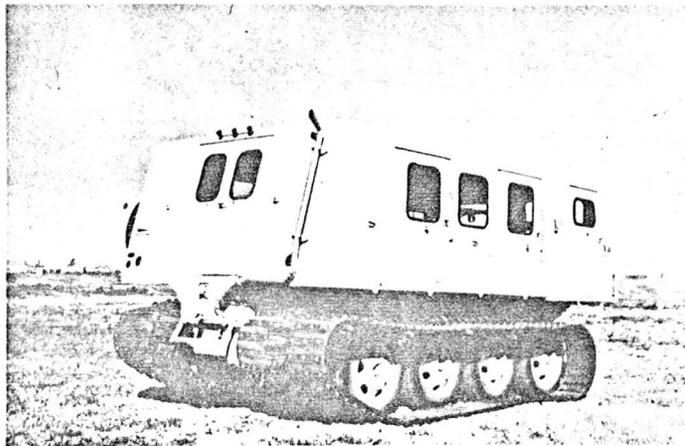
Model RN-110 Personnel Carrier



Model RN-110 Crew-Cargo Carrier & RNT-75 Trailer



Model RN-110 Crew-Cargo Carrier & RNT-75 Trailer



Model RN-110 Personnel Carrier

Fig. 2 - Nodwell Model RN-110 equipped for use in the antarctic

summer months. These lakes are from a few to 100 ft or so across and from a few inches to 1 or 2 ft deep, and the lakes are separated from each other by ice ridges or other separating barriers which form a never-ending series of obstacles which the vehicle must go up and over, providing a very rough operating condition for the vehicle.

While snow is the main terrain which must be traversed during the winter, the type of snow found in the arctic is not difficult, commonly being called wind-blown concrete by those people who operate in the arctic. This snow, because of its dry texture, and because it is usually packed by the prevailing winds, will support relatively great weights. In some areas, it is possible to land heavy transport planes with very little runway preparations. Vehicles which have ground pressures as high as 10 psi or more are very successful when operating during the arctic winter months. In addition to the special vehicles for use in the arctic, the snow there is so firm it will support considerable loads, and large tracked vehicles, such as the large Caterpillars, have been successful in operating during the freeze-up months of the arctic.

When operating over tundra, it is found that most of the vehicles which do not exceed about 4 psi are relatively successful unless too many passes must be made over the tundra. One problem recently encountered in the arctic area north of the Brooks Range is the tearing up of the tundra by the tracked vehicles to the extent that erosion sets in and washes out the area chewed up by the tracked vehicles, causing channels to be cut down to the permafrost, leaving a rough surface for any use by other equipment. Providing equipment for operation on tundra without causing erosion will challenge the designer.

The subarctic is those areas below the tree line, as represented by areas in central Alaska or northern Canada. The main problem encountered here is the ability of the vehicle to traverse the soft muskeg, to handle a great variety of downed timber, such as scrub spruce and scrub birch found in great density in the areas, and also the ability to handle outcroppings of intermittent rocks when operating in areas such as the Kinia Peninsula where a great amount of rocks and downed timber must be encountered, sometimes on rather

precipitous slopes. One of the major uses for vehicles in the subarctic areas of northern Canada and central Alaska has been that of geophysical exploration by the oil companies. The vehicles which have been most successful in doing this type of work over these terrains are those developed by the Robin Nodwell Corp., which is now the Flex-Track Nodwell Corp., the Nodwell RN 110, and also those vehicles produced by Foremost Developments Co., such as the 6T and 8T Foremost vehicles, and the Juggernaut vehicles produced by Thiokol Chemical Corp., the cross-licensees with the Foremost people. An example of the Robin Nodwell vehicle is shown in Fig. 3. Fig. 4 shows the Foremost vehicle. Fig. 5 shows a Juggernaut vehicle for use in Alaska, and Fig. 6 shows a Thiokol Rangemaster 600 Series vehicle.

The vehicles for use in the subarctic, particularly by the geophysical companies, have load carrying capabilities from 6-10 ton, and in some cases, carry as much as 30 tons. Fig. 7 shows a 30-ton payload vehicle produced by the Foremost Corp. of Calgary. These vehicles usually exert about 1-1/2 to 2-1/2 psi unloaded and up to 4 or 4-1/2 psi fully loaded.

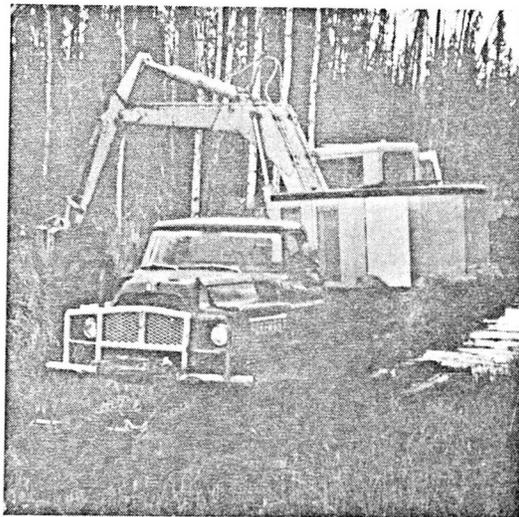


Fig. 4 - Foremost Model 8T vehicle doing ditching in northern Canada

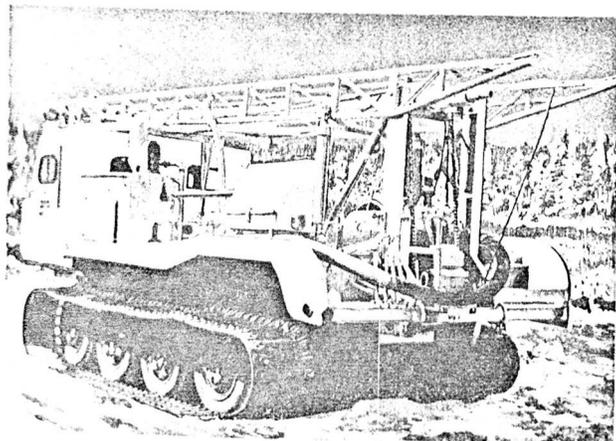


Fig. 3 - Nodwell Model RN-110 equipped with a geophysical drill unit as used in Alaska



Fig. 5 - Thiokol Chemical Co. Model 6T with drilling unit in Alaska

Their most important characteristics are their general dependability and their ruggedness, giving them great capabilities of operating under very difficult conditions for relatively extended times.

SWAMP AND AMPHIBION OPERATION - Vehicles used in operation in swamps are three types, first, those tracked vehicles which are very successful in swamp areas, but do not possess amphibion or swimmer characteristics; second, smaller tracked vehicles which have the amphibious characteristics; and third, a wide variety of large tired vehicles, or pontoon vehicles, which have enough flotation in the tires or the hollow pontoons to give swimming characteristics.

Vehicles in the first area, which are tracked vehicles but do not possess amphibious characteristics, are best represented by the Juggernaut Series produced by Thiokol Chemical Corp., the Foremost vehicles produced in Calgary, and the Bombardier vehicles produced in Quebec. These vehicles have found wide usage in the swamp lands of the southern United States and other areas of the world where they successfully negotiate typical cyprus stump or mangrove type swamp. Generally, the vehicles are operating over a floating mat of vegetation and debris and are able to traverse this mat many times without breaking through. These vehicles have been used principally for the construction of the high tension lines and pipelines across these treacherous areas and for logging of pulpwood for the paper manufacturers. In addition, the vehicles have done an excellent job in the boggy swamps of the northern United States, such as those found in northern

Minnesota or areas just north of the Canadian-United States boundary line.

The vehicles have been successful in transporting materials for the construction of oil and gas lines in the areas where it becomes so soft that heavy tracked vehicles normally used in pipeline construction cannot operate unless corduroy mat type roads are constructed ahead of them. Figs. 8 and 9 show the Juggernaut vehicles operating in swamp conditions in the southern states. Fig. 10 shows a 30T Juggernaut vehicle produced by Thiokol. This vehicle is capable of hauling a payload of 30 ton and, in many cases, has carried 50 ton loads. It is principally used for traversing the swampy and slick red mud areas found in southern Mexico. This vehicle has been operating for about three years near Vera Cruz in support of oil drilling operations during the rainy season. When tired or heavy tracked vehicles have been immobilized during the rainy season by the slick muds, this 30-ton vehicle has been able to operate, hauling supplies and moving the drilling rigs from one area to another. Fig. 11 shows a Swamp Spryte vehicle produced by Thiokol Chemical Corp. which has excellent operating capabilities in the swamps or tidal-flat areas, but in addition, has swimming capabilities of about 4.2 mph in open water. It has consistently shown its ability to traverse the gray or twilight area between the solid ground and the open water of the tidal-flat areas and has good dry land speeds of about 35 mph. This vehicle has been used principally for personnel transportation through the swampy areas and for maintenance support for larger vehicles

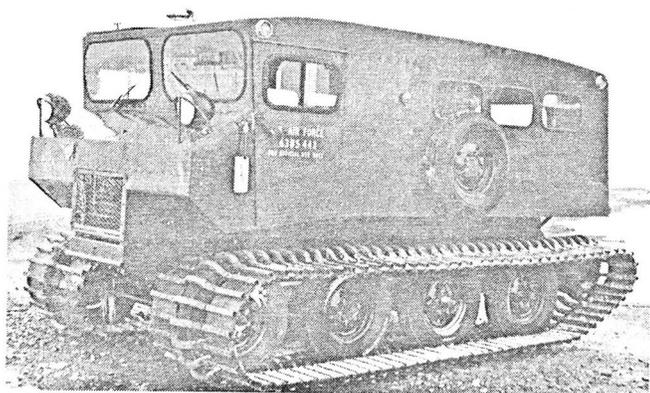


Fig. 6 - Thiokol Chemical Co. Model 601 vehicle as used by the Air Force in Alaska

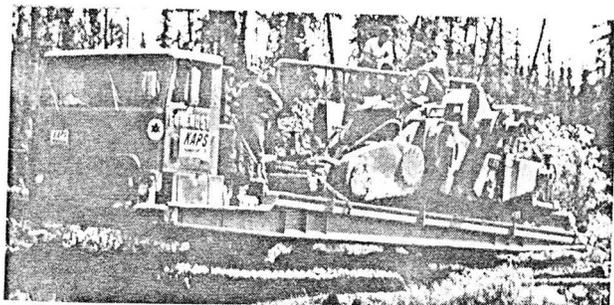


Fig. 7 - Foremost Model 30-T operating in muskeg



Fig. 8 - Thiokol Chemical Co. Model 8T Juggernaut used for a towing vehicle in Louisiana swamps



Fig. 9 - Thiokol Chemical Co. Model 8T Juggernaut equipped with a drill and towing a concrete base for a high tension line

operating in swampy conditions. For the third area of swamp operations are those vehicles of the pontoon type, such as those produced by the Quality Marsh Co. of Thibodeau, La. These vehicles utilize a rigid metal pontoon and slide an all-metal track around this pontoon on rollers or runner plates. Because of the rigid pontoon, they have excellent flotation in traversing the vegetation mats found in the swamps, and then the pontoons have displacement great enough to provide the vehicles with true amphibion characteristics. Their swimming speed is not great, but they do have the capabilities of crossing the canals and other open water areas which criss-cross the swamp area of the southern states.

The other vehicles widely used are those which utilize large Terra-tires of low pressures. These tires normally are operated at 2-6 psi and have enough displacement to float the vehicle. In some cases, these large tired vehicles have payloads as great as 5 ton, and because they do possess the amphibious characteristics, they do an excellent job in most areas of the swamps. They run into some difficulty in the swamps which have the dense undergrowth and in those areas which have a great amount of downed timber and cyprus stumps. However, generally speaking, the large tired swamp buggies have done more work in the swamp areas of the southern states than any other type of vehicle. They are made in a wide variety of sizes, from very small 2-man machines, to those capable of carrying 5 or 6 ton payloads, and are built by several companies, such as the Gemco Co. and Ardco Co. Most companies producing these vehicles are located in the southern Texas and Louisiana areas. Figs. 12 and 13 show examples of the large Terra-tire type swamp buggies.

OVER-SNOW VEHICLE - There is a wide variety of over-snow vehicles and most of these over-snow vehicles are very specialized machines. Because of their generally great mobility capabilities, they are also relatively successful in some other environments. The soft snows being one of the most difficult types of environment in which to operate means that the vehicles must be relatively light and usually specially constructed to meet the specific use intended for the vehicle. The purchaser of the machine may be a ski resort, a utility company, or some other organization having a special requirement to reach certain areas in the winter months. The vehicles discussed here are the vehicles for operation by ski resorts, utility companies, ranches and other agricultural users, and the use by individuals for sport or personal transportation of one kind or another.

One of the most important markets for over-snow vehicles today is the use of the vehicles for grooming the slopes and for general maintenance around large ski resorts. The use by ski resorts for slope grooming is also one of the most demanding uses for the vehicles. Grooming of slopes in order to provide a surface which is smooth and constant for use by skiers is a relatively new innovation. The first work of this type was probably done about 30 years ago by Sun Valley and one or two other large resorts. Slope grooming at the ski resorts in the United States is generally quite far ahead of those in Europe; however, European ski resorts are catching up fast. The resorts in the United States have led in the area of slope grooming, and particularly in an attempt to study what does the best job of slope grooming and to accomplish it from a well-planned approach as compared to just hooking any device behind the vehicle and hoping the grooming job is adequate.

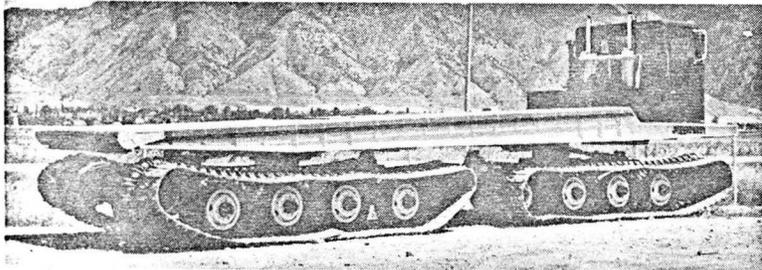


Fig. 10 - Thiokol Chemical Co. Model 30T Juggernaut used for hauling supplies in the oil fields

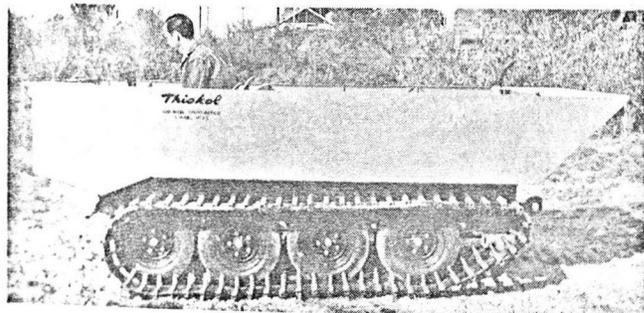


Fig. 11 - Thiokol Chemical Co. Model 1301 Swamp Spryte an amphibious vehicle with excellent swimming ability

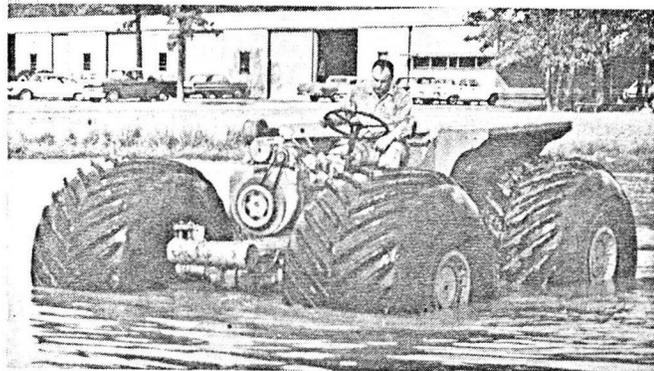


Fig. 12 - Ardco swamp vehicle with floating capabilities

Slope grooming was not done to any great extent prior to World War II, but shortly after World War II, considerable work was begun, particularly at Sun Valley. Most of the slope grooming during this period, and continuing for several years, was done with a variety of devices which were generally towed behind the Tucker Sno-Cat vehicles. The Tucker Sno-Cat vehicles utilize a rigid metal pontoon and roll a linked metal track around the pontoon. They do a very successful job. Their climbing performance is generally adequate, and the only drawback to the vehicles is that the maintenance of their tracks is high. The people at Sun Valley Ski Resort acquired a fleet of several Tucker vehicles many years ago, and then developed a variety of drags and other grooming devices which did a very good job of controlling the moguls and providing a smooth surface for the skier to use each day. The skier, of course, could then depend on the slopes being relatively smooth and constant for him so that he could enjoy his skiing rather than fight the

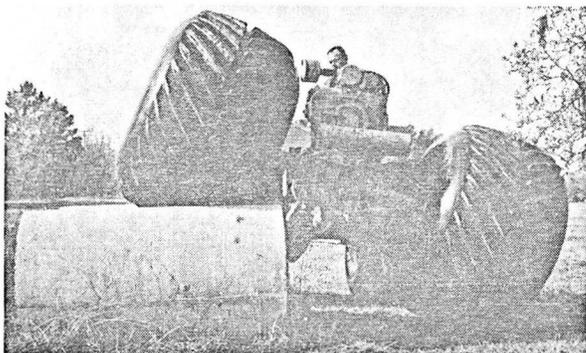


Fig. 13 - Ardco swamp vehicle showing the articulating ability of the vehicle

rough slopes. Fig. 14 shows a Tucker Sno-Cat working on a ski slope.

About eight years ago, there appeared on the market a series of vehicles produced by Thiokol Chemical Corp. called the Snow Spryte Series. These vehicles were 2-track, ski-steered vehicles with flexible rubber track design; the track rolling around rubber tires. The main advantage of this type track over earlier models or rigid type models was the reduced amount of maintenance required to keep the tracks of the vehicles in operating condition. During the last four or five years, the vehicles produced by Thiokol Chemical Corp. have become preeminent, both in the United States and in Europe, in the area of slope grooming for ski resorts. They have produced several models from very large super wide track vehicles to relatively small vehicles: larger vehicles, of course, being used by ski resorts with large areas and some of the smaller vehicles being used for the small ski resorts which only have a hill for the beginning skier.

One of the most successful over-snow vehicles is Thiokol's Snow Spryte, Model 1201-B, wide track vehicle. This vehicle has tracks approximately 46 in. in width and ground pressure of 1/2 psi. It is able to work ski slopes as steep as 70% and maintains the same general workability whether sidehilling or descending slopes. Fig. 15 shows the 1201-B wide track Snow Spryte.

Ski resorts started out working only their most gentle slopes, but as the smoothness of these slopes became apparent and increased the pleasures of skiing, the demand has been that the resorts want to work ever-increasing gradients and most resorts now think nothing of continuously working in the 60-70% slopes. Generally, the steeper the slope, the greater the tendency for the slope to develop moguls due to the criss-cross traversing of the skiers. It is necessary that

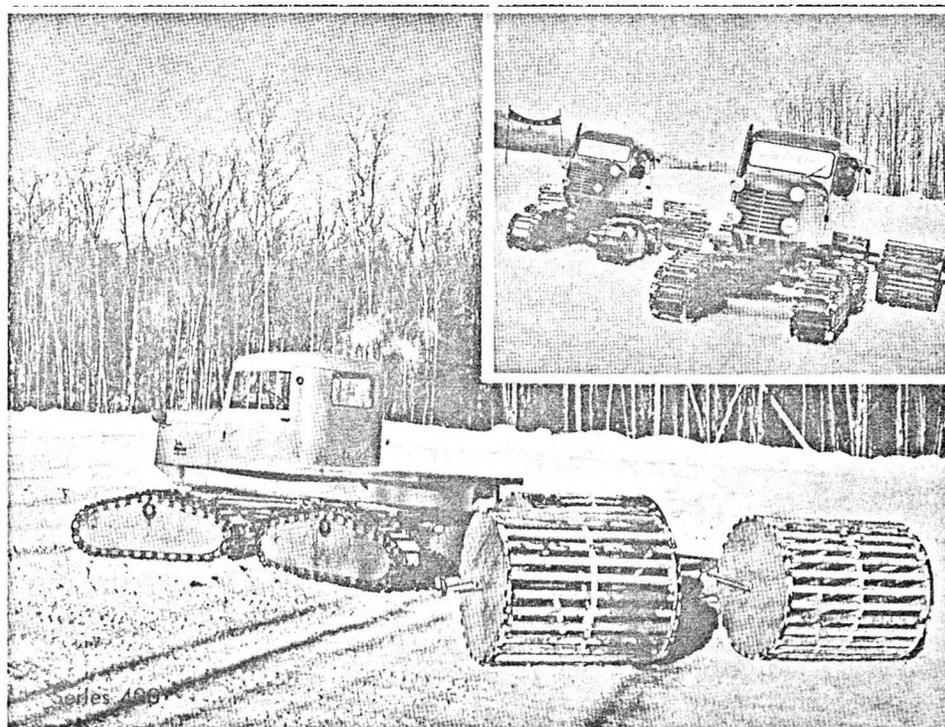


Fig. 14 - Tucker Snocat pulling ski slope grooming rollers

these moguls be planed or smoothed down periodically. The more often, the better, if the slopes are to be maintained in good condition, and for this mogul planing requirement, Thiokol has developed several devices. Fig. 16 shows a Snow Spryte pulling a mogul planer. The mogul planer has the capability of first cutting the top off the mogul, depositing it in the valley or gully between the next moguls, and then rolling to mash down the lumps of snow left when the mogul is planned, and finally a drag is pulled behind which again smooths and pulverizes the snow and returns it to a skiable condition. Fig. 17 also shows a 1200 Series vehicle being used as a team to very quickly groom an entire slope.

Fig. 18 shows a Snow Spryte vehicle equipped with a mogul patrol. The mogul patrol, in effect, extends the wheel base of the vehicle and provides an extended arm with a ski on the front for steering the vehicle. In addition, downward pressure can be applied to this arm by hydraulic means so that the vehicle becomes rigid from the front ski to the rear

of the vehicle, and thus extends the wheel base and allows the blade on the front of the vehicle to cut the moguls without the vehicle pitching in a fore and aft direction.

The effect achieved is similar to that achieved by a road grader or a land leveling plane. By extending the effective wheel base to reduce the pitching moment, it is possible for the vehicle equipped with the mogul patrol to very rapidly remove large moguls from the ski slopes. In addition, it has been possible for a vehicle equipped with a mogul patrol to work steeper slopes than has ever been attempted before by any other device for controlling moguls, particularly those devices which are towed behind the vehicles.

Thiokol vehicles, in the last few years, have been introduced into Europe and have been distributed under the name of Ratrac. Fig. 19 shows a Ratrac SW vehicle which is a super wide vehicle with tracks approximately 60 in. in width. Fig. 20 shows a Thiokol 2100 Series vehicle which is very similar to the previously mentioned vehicle, and Fig. 21 shows a Ratrac S vehicle which is the versatile working vehicle which can be equipped with grader blades and rollers and drags, and equipment for special purpose slope grooming.

One interesting and very worthwhile result of slope grooming has been in the area of ski racing. Prior to grooming slopes, whenever a ski race of importance was held, such as the National or World Cup Races, or races which extend over

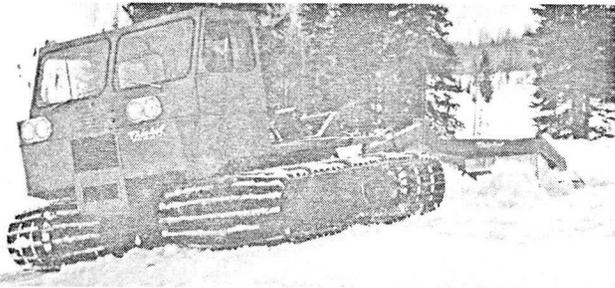


Fig. 15 - Thiokol Chemical Co. Model 1201-B WT Spryte. A very successful ski slope grooming vehicle

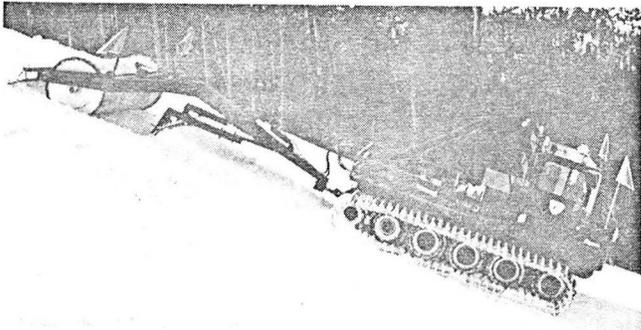


Fig. 16 - Thiokol Chemical Co. Model 12015 pulling a Bradley mogul planer for smoothing ski slopes



Fig. 17 - A team of Thiokol Chemical Co. Model 1201B vehicles working on ski slopes at Winter Park, Colo.



Fig. 18 - Thiokol Chemical Co. Model 12018-WT vehicle equipped with stabilizing mogul patrol, hydraulic dozer blade, and hydraulic drag box for smoothing ski slopes

several days, such as the Olympic Games, the success of the ski racer has depended upon two factors. First, his own natural ability, and second, and sometimes of equal importance, has been the drawing for the position in which the skier ran. If the skier was fortunate enough to draw one of the first numbers, it meant that he would be going down slopes that had not been skied to any extent. If he was toward the end of the sequence of racers, it meant that he would be skiing slopes that had been badly cut up by 70 or 80 previous skiers, and this meant that the skiers toward the end of the race were working at a very serious disadvantage in trying to compete on equal terms with those fortunate enough to draw the early spots. Through the proper use of slope grooming, it has become possible to reduce the advantage held by the ski racers who run first in the day. In many cases, the trial runs are made early in the morning, and then the slopes are

regroomed and brought back to relatively new or undisturbed condition before the finals in the afternoon. This reconditioning or regrooming of the slopes has, in effect, reduced the ski races to the point where more often the skier with the best ability will consistently win the race, rather than have his chances affected by which position he runs.

The Ratrac vehicles produced by Thiokol and distributed in Europe were used exclusively at the 1964 Olympics at Innsbruck and the 1968 Olympics at Grenoble. The slopes were groomed many times during the running of the Olympics in order that a constant surface on the slopes could be presented for the use of the skiers. The slopes were groomed in the morning, they were usually groomed at midday, between the morning and afternoon races, and then, of course, worked over extensively at night, so that the best possible slope would be available for the running of the races. The successful effect of this slope grooming was probably best demonstrated by the fact that the few best skiers consistently won all the races. In addition to their great individual abil-

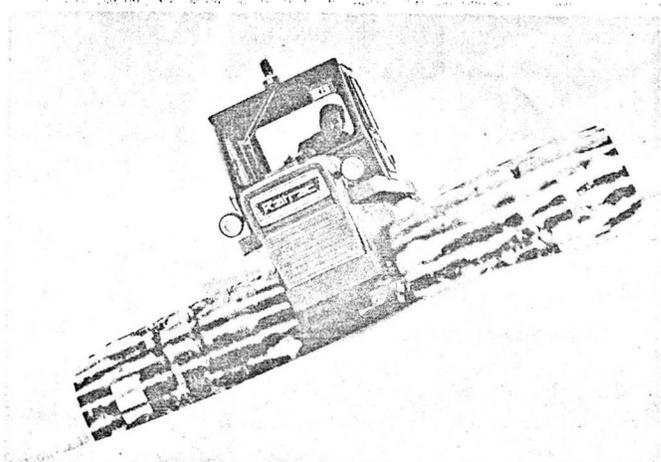


Fig. 19 - Thiokol Chemical Co. Model 2100 vehicle distributed in Switzerland under the name of Ratrac, a super-wide vehicle for ski slope grooming



Fig. 20 - Thiokol Chemical Co. Model 2100 wide-track vehicle

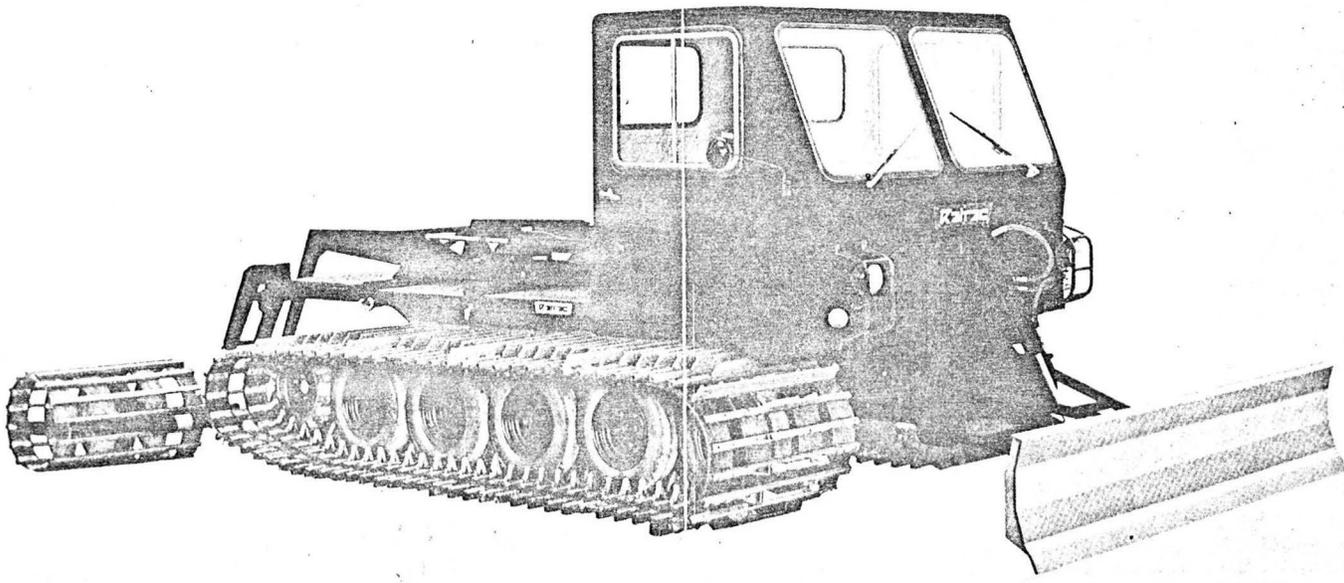


Fig. 21 - The Swiss Ratrac version of the Thiokol Chemical Co. Model 12-1-B vehicle equipped with slope grooming devices

ity, their consistent performance has to be related to the consistent quality of the slopes on which they were able to ski. Because of the success in grooming of the slopes at both Innsbruck and Grenoble, the Ratrac vehicles have been invited to exclusively handle the slope grooming at the 1972 Olympics in Japan.

The second main category of users of over-snow vehicles is utility companies. Utility companies, such as the telephone companies and the power and light companies, are continually faced with the problem of being able, in emergencies, to reach any area where they have lines, or repeater stations, or other equipment that must be kept operating under any conditions. Generally, when equipment, such as microwave stations, gets out of order, it is under the worst possible climatic conditions, and the failure of the equipment is associated with the storm conditions. During these storms, it is extremely important that repair crews be able to reach these stations under any possible condition, and the stations are located in remote areas or on top of the higher mountain peaks. As a general rule, the utility companies have tried to make it possible that under no condition would they have any facility out of order any more than an hour or two, which means that the crews must leave their home working base, transport the vehicle to the mountains, or drive to a garage near the mountains where the vehicles are kept, and then under the worst storm conditions and in the softest

snows still be able to get to the station that has the trouble with the least possible delay.

To meet the requirements of the utility companies, the main criteria on which they judge a vehicle are: first, mechanical dependability, and second, its overall climbing performance. Can it give reasonable operating capabilities under the most severe conditions that can be encountered in stormy mountain areas? Fig. 22 shows a Thiokol 1200 Series vehicle as equipped and used by the utility company for transporting men, tools, and repair materials to remote stations. These vehicles can be equipped with a 2-man cab and have considerable cargo carrying capacity or can also be equipped with 4, 8, or 10-man cab. Vehicles for this purpose have also been produced by Tucker Sno-Cat Corp.; however, the vehicles produced by Thiokol have generally come into wider favor because of their ability to handle terrain and surfaces other than snow. Some of the most difficult conditions in which to service the remote stations are those during the spring months when violent storms often strike, and there are considerable lengths of terrain which are of intermittent mud and rocks which must be traversed, as well as traversing the snow. The rubber tracked vehicles produced by Thiokol have been quite successful in handling the varied surface conditions, in addition to the snow, without serious wear and tear on the vehicles.

The next use of the vehicles is by ranches and for other agricultural uses. In steadily increasing numbers, the vehicles are being used by large ranching companies, particularly for the feeding of large herds of cattle during the winter months. Fig. 23 shows a Thiokol Model 1404 Imp vehicle pulling a load of hay out to feed cattle. Some of these vehicles are capable of carrying and towing loads of 150 bales or more of hay, making it possible to feed very large beef herds in a relatively short time. Although, generally, the snow conditions in which these vehicles must operate are not too severe, as they seldom exceed 2-4 ft in depth, and the vehicle is usually following the same path each day. The dependability of the vehicle with the minimum of maintenance does become a factor because usually agricultural users are not noted for the efficient maintenance of their vehicles. They expect them to start and go under any condition with a minimum of maintenance. The use of the vehicle for cattle feeding operations is expected to increase as the successful use of the vehicle becomes known.

In addition, some of the fish and game departments of both the federal government and the state government are using the vehicles in increasing numbers for control of big



Fig. 22 - Thiokol Chemical Co. Model 1202-B equipped for use by utility companies



Fig. 23 - Thiokol Chemical Co. Model 1404 Imp used for feeding cattle on large ranches

game, feeding of large elk herds, and other uses associated with the maintenance of wildlife and wildlife refuges.

The last use of the large over-snow vehicle, for sport or individual transportation use, is also increasing. Although the larger over-snow vehicles are relatively expensive and generally beyond the needs of most individual users, there are a few people who are buying the vehicle for personal transportation or more usually, a group of several people are going together and buy a vehicle for their mutual use. One use by these groups is for those who have summer homes located in remote areas. Having these vehicles available means that they can now get into their homes and use them as year around vacation or sport retreats. In some areas where the summer homes are under the control of a development corporation, the corporation has provided a vehicle for use by the owners of the summer homes at a nominal rental fee. Most of the owners of the summer homes depend upon the small ski sport vehicles for personal transportation, but when it becomes necessary to take in larger groups or large amounts of supplies, they are finding that even the larger expensive over-snow vehicles have use in their areas.

Another use for the vehicles which has developed considerably in the sport area, is that of the use by big game guides for taking hunting parties into very remote areas. Considerable numbers of the vehicles are now being used in Alaska for transporting hunting parties into remote areas and then carrying out the big game after the hunting party has been successful. Many areas are being hunted now which were not even accessible by airplane and perhaps could only be made accessible through the use of helicopters, which are very expensive for transportation of personnel and their equipment for sporting purposes only. Fig. 24 shows a vehicle being used for big game hunting.

FUTURE TRENDS IN VEHICLE DESIGN

The following are areas which I believe will be most important in future trends for vehicles in the off-highway and over-snow category.

In the larger vehicles, there is going to be continually increased need for greater payload capabilities, particularly

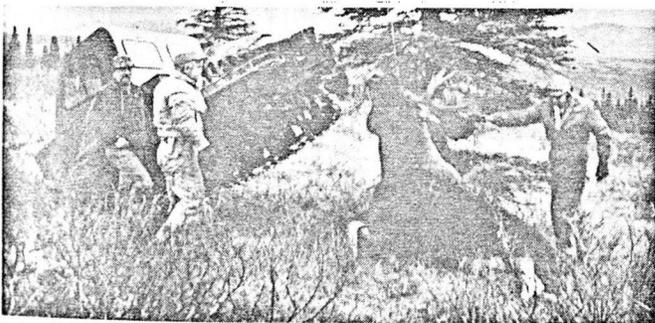


Fig. 24 - Thiokol Chemical Co. Model 1404 Imp used for hunting big game in Alaska

vehicles used in the heavy industries, such as the oil industry and geophysical exploration areas. This is also true in the pipeline construction and high tension construction. There will also be an ever-increasing need for improved dependability. Because of the very nature of the vehicles and the terrain in which they operate, dependability is always a factor. Many users of the vehicles are getting by with them only because there is no other alternate available, but they are paying a high penalty in maintenance cost and in downtime due to failure of the vehicles under the arduous conditions. There are great areas for improvement in vehicle dependability.

Vehicles must also be reduced in cost if the market is to be expanded, or if not reduced in cost, the cost must be justified by improvements in dependability and reduced maintenance and extended life.

In looking at the smaller vehicles, there is a great need for a vehicle which fills the spot in between the small ski-steered sport type vehicle and the lowest priced vehicle now available from manufacturers of the large vehicles. There is a market of users who want a vehicle for individual use or big game hunting or general exploration, similar in cost, and meeting the need of the user who would ordinarily buy a 4-wheel drive station wagon, or a Jeep, or some of the specialized dune buggy equipment. At this time, many of the vehicles available, which are successful in handling most terrain, cost approximately twice that of a Jeep or similar equipment, and this puts it beyond the pocketbook of the average individual user. There is a great market available in this area; however, it must be done at a cost that the user can afford, and the vehicles must have improved capabilities over that provided by the small wheeled type vehicles presently available.

VEHICLE IMPROVEMENT AREAS

I believe the greatest opportunities for improvement in the design of the vehicles lie in four general areas: first, in the area of suspension; second, in increased track life; third, in improved drive systems or transmissions; and fourth, improved steering system.

SUSPENSION - There is a need for suspension systems which have increased travel and shock absorbing characteristics without increasing the weight or the cost of the vehicle. I believe that the use of spring media, such as rubber, will increase because these media can be used with no problems of linkage or lubrication requirements. All bearings, bushings, and seals must be improved or eliminated from the suspension system, if possible, now the system becomes relatively impervious to the abrasive environment in which it must operate. The use of rubber, or other similar media in sheer, in torsional sheer, or in compression, will probably provide better suspension means than by any of the conventional metal-to-metal type suspension systems.

TRACKS - Track life has always been a problem with any off-highway vehicle. Great improvements have been made

in some areas, particularly in those vehicles produced by Thiokol Chemical Corp., where track failure on their media size vehicle, such as the Snow Spryte, has practically been eliminated. Greater dependability is definitely required on some of the smaller vehicles and on the very largest vehicles which are available in the field. The larger vehicles, especially, are called upon to operate in abrasive conditions and means must be found for providing greater track life and reduced cost to the industrial users of the larger vehicles.

DRIVE SYSTEMS AND STEERING SYSTEMS - Probably the area of greatest potential available to the designer of off-highway, over-snow vehicles is the area for improving the drive systems and steering systems. These are included under the same general heading because the trend is to go to a single system which provides both the transmission reduction effect, as well as the steering capabilities for the vehicle.

During the past four or five years, hydrostatic drives have shown great improvement, and there is now available to the designer of the vehicles a variety of hydrostatic components which are in relatively high production. They have greatly improved dependability and efficiencies which are adequate for vehicle use. Hydrostatic drives are not new, as the principles have been known and some components have been available for more years than there have been over-snow vehicles, some drives being installed commercially as early as 1906. However, the cost has always been high and the efficiencies have been marginal. Hydrostatic drives have been successful for many years in heavy equipment, such as cranes, railroad equipment, and gun turret equipment on ships. It is only recently that several companies have been able to produce the components with the dependability and efficiencies demanded and still do it at a reasonable cost. Preeminent in this area are the drives presently in production at the Sundstrand Co., Vickers, and others.

Hydrostatic drives are presently being applied to a wide variety of vehicles in the agricultural field, such as hay swathers, combine harvesters, wheeled tractors, such as the International Harvester Model 656, and are being applied to an ever-increasing number of tracked vehicles for specialized purposes.

One new tracked vehicle, which has just appeared on the market and utilizes a full dual path hydrostatic drive, is the Spider vehicle produced by Foremost Ltd. of Calgary. This vehicle uses hydrostatic components for both steering and drive ratio reduction purposes. It is specifically designed for over-snow transportation and for ski slope grooming.

Hydrostatic drives have two capabilities, or give two freedoms to the designer which no other type drive, at present, can give. First, it is possible to incorporate the steering and transmission effect in the same components; second, the components can be located without consideration for the location of drive shaft, universal joints, drop boxes, and other components which greatly limit the ability of the designer to do an adequate job in both locating vehicle drive compo-

nents and also providing the strength required in the structure of the vehicle.

Where dual path hydrostatic systems are used, the transmission reduction effect is available and the dual power paths can also be operated for steering purposes. The transmission, or steering effect is available in an infinitely variable ratio from full forward to full reverse. Turns of very gentle radius or spot turns about the center of gravity of the vehicle are available to the designer, and the turning effort is applied to the vehicle in a manner that greatly reduces the stresses put on the vehicle's suspension system and tracks.

Several tracked vehicles are now operating with full hydrostatic transmission and steering systems, and it is my opinion that the number of vehicle types and sizes will increase very rapidly as these components are made available to designer at steadily lowering costs.

Another inherent advantage of the hydrostatic system is that the power can be applied very slowly and very gradually for startup purposes while the engine is operating at a constant speed. This means that under difficult or arduous conditions, the creep speeds of the vehicle can be very well controlled while the full power of the engine is available even though the vehicle is moving at a very slow speed. This means that precipitous slopes, or difficult areas, can be successfully negotiated with limited stress on the vehicle or danger to the operator.

It is possible with hydrostatics to locate the final drive components completely independent from the engine. The designer has great freedoms and the vehicle structure can be designed in such a manner that the structure can be located directly in the stress path to best absorb the forces being applied to the vehicle without giving much consideration to the drive components as is required with conventional mechanically driven vehicles. This should mean that the vehicles can be constructed by simpler fabricating means at reduced cost, the weight of the vehicle should go down, and the dependability of the vehicle should increase.

At this time, the cost of the hydrostatic components is still a margin above the components available for mechanical drives, but the design freedom, the dependability, and other factors which are inherent in the hydrostatic system, I believe at this point, still make it justifiable to apply hydrostatic components to most sizes of off-highway vehicles. As the usage of the components goes up, the cost, in turn, can be driven downward until the price differential between the hydraulic components and the mechanical components will be eliminated, or it may end up in favor of the hydraulic components because of the simplification of the overall design of the vehicle. While the cost and efficiency of the hydrostatic components may not make them acceptable for some of the high speed wheeled vehicles, it is my belief that the inherent advantages which they offer designers more than justify their use in any of the tracked vehicle approaches in the off-highway and over-snow vehicle field and that during the next few years we will see a fast growing trend to incorporate these components in the majority of these vehicles.

GENERAL AREAS OF FUTURE INTEREST FOR VEHICLE DESIGNERS

In addition to the specific design areas of vehicles, which I believe the designer should consider carefully in the future, following are some general uses for vehicles which offer opportunity for manufacturers in the next few years.

Until the last season or two, ski resorts and many other users of over-snow vehicles have tended to judge the vehicles on only one criteria: how steep a hill will they climb? The performance of the better machines has now improved to the point where climbing ability is adequate, and now other vehicle characteristics are playing an increasing role. Factors such as vehicle life, percentage of downtime, operating costs for fuel and repairs, and vehicle amortization are being considered by area managers. More important, the whole approach to slope grooming and ski area maintenance is rapidly changing. Managers are finding the vehicles offer many more possibilities than just pulling a roller up and down a slope.

Vehicles are being equipped with an ever-increasing variety of devices for grooming slopes, maintaining lifts, transporting personnel, hauling supplies to uphill facilities, hauling snow, and many other uses. There is great opportunity for creative thinkers in these areas.

The more advanced-thinking ski area managers are talking about the concept which I call snow farming. They realize the one basic variable controlling the success of

their resort is the availability of snow. They are trying to reduce the availability of snow to a constant factor, first by supplementing natural snow with snow making equipment, but equally important is the conservation of the available snow by packing, rolling, moving snow from areas of heavy cover to the thinly covered high usage areas. In addition, how to turn hard icy slopes quickly into finely powdered or granulated snowy slopes economically is being done with some success.

Successfully meeting and solving these problems means a longer season, safer slopes, reduced liability from injuries, and overall, a more profitable operation with well-satisfied customers.

Continued development of vehicle designs to expand their usefulness and improve the economics of operating ski areas, I believe, offers great opportunities, and it is in these areas that we are concentrating a large portion of our creative effort.

REFERENCES

1. Walter Ernst, "Hydrostatic Transmissions, Past, Present, and Future." *Hydraulics and Pneumatics*. November 1967. p. 134.
2. "Vehicles for Tomorrow." *Hydraulics and Pneumatics*. September 1968. p. 100.
3. William Tucker, "Fluid Systems -- The Modern Revival." *Machine Design*. Jan. 5, 1967. p. E-2.



This paper is subject to revision. Statements and opinions advanced in papers or discussion are the author's and are his responsibility, not the Society's; however, the paper has

been edited by SAE for uniform styling and format. Discussion will be printed with the paper if it is published in SAE Transactions. For permission to publish this paper in full or in part, contact the SAE Publications Division and the authors.